ITC Special Session

Next Generation
Instrumentation Bus

Session Schedule

0800 Session Introduction
0810 Instrumentation into the 21st Century
0830 NexGenBus Overview

Break

0900 Assessment of Fibre Channel

Break

1000 Simulating an Instrumentation Network

Break

1100 The NexGenBus Profile and Discussion

--- Coming up ---

Instrumentation into the 21st Century

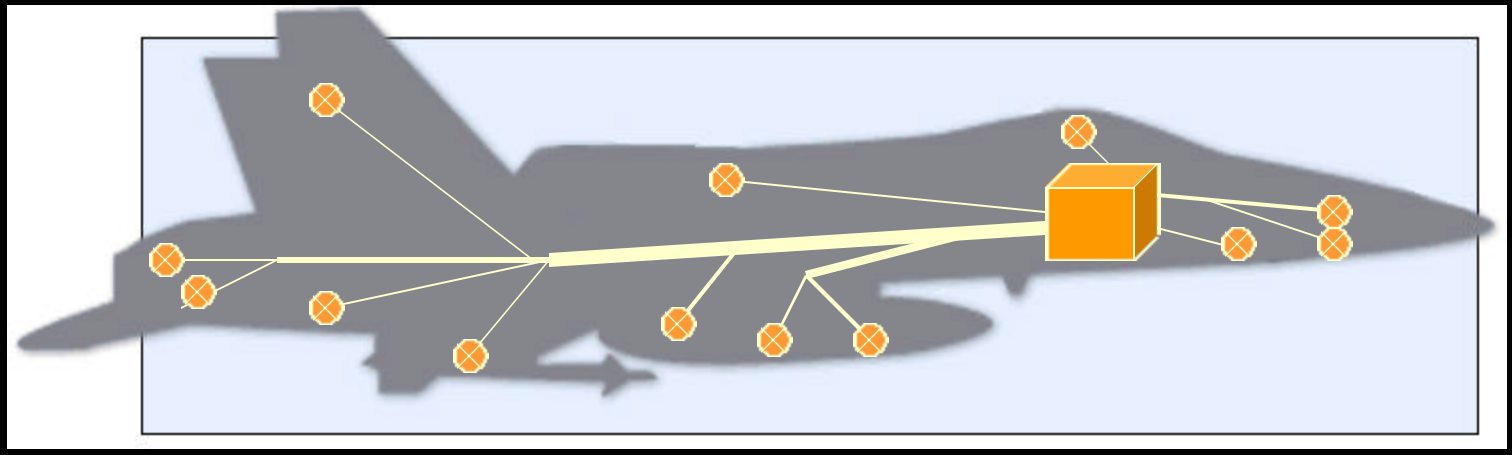
Vehicular Instrumentation into the 21st Century

Dan Skelley

Deputy Director, Test Article Preparation, US Navy

Instrumentation System Topologies

Centralized Data Systems



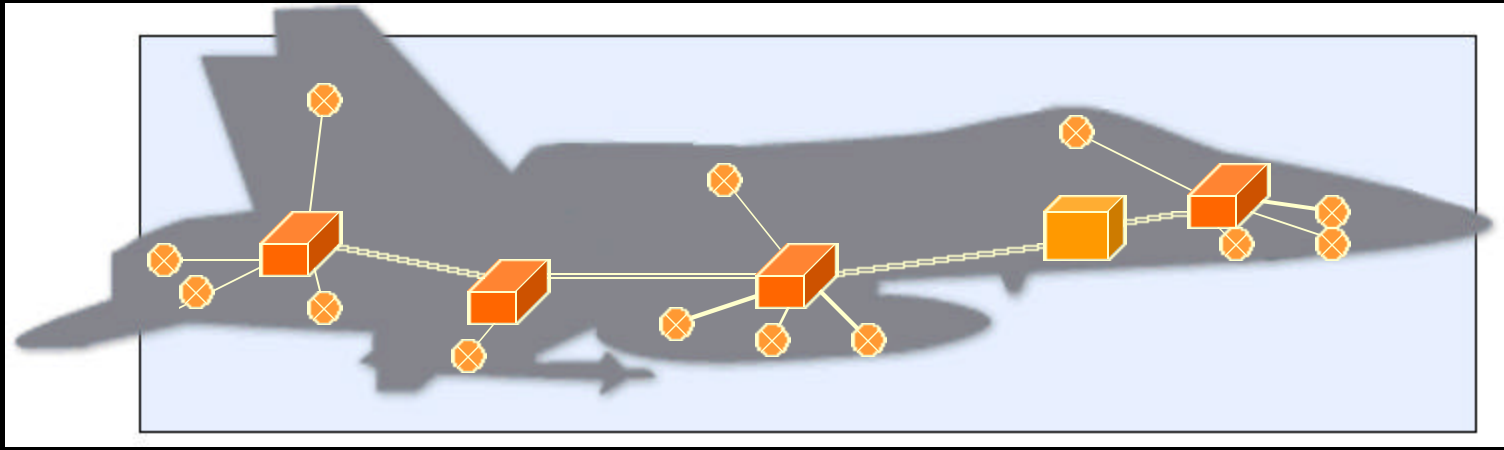
n Transducers/Avionics taps

Varying sizes of wire bundles

Instrumentation System Unit
Interface to data signals
Formatted data output to:
Recorders, Transmitters, Etc

Instrumentation System Topologies

Distributed Data Systems



n Transducers/Avionics taps

Varying sizes of wire bundles

Communications Bus

Instrumentation Control Unit

Formatted data output to:
Recorders, Transmitters, Etc

Transducer Interface Units

Interface data signals onto the bus at the request of the control unit

Current System Limitations

- Unable to meet data rate requirements
- Aging technology
- Closed architecture
- Network incompatibilities

DoD Policy Trends

- Acquisition Reform
- Decreasing budgets
- Shorter cycle times
- Open architecture and COTS

Commercial Technology Trends

- Growth of the Internet
- Proliferation of PC and LAN technology
  - Price/performance ratios are plummeting
- Data packets are the universal data structure

Future Instr. Systems Must:

- Have open architecture
- Utilize COTS hardware/software
- Easily interface with global network infrastructure
- Leverage commercial standards
- Meet exponential growth in data requirements
- Easily incorporate leading edge technology

Data Acquisition Networks

- Network based instrumentation system
- Data is formatted and moved in packets
- Compatible with network infrastructure
- Open architecture based on Commercial standards

Leading the Way

- Next Generation Instrumentation Bus
  - Vehicular Data Acquisition Network
  - High Speed
  - Comforms to OSI Communications Model to facilitate technology insertion
- Air Force SBIR AF99-302
  - Fibre Channel bridge to legacy instrumentation standards
  - Demonstrate CAIS to Fibre Channel bridge

The Challenges

- Non-standard packet structures
- Leading industry
- Bandwidth concerns (RF and recorder)

Bandwidth Concerns

- RF Bandwidth
  - Reduced RF spectrum available
  - Data requirements keep increasing
- Recorder Bandwidth
  - NexGenBus will have a data rate of 800 Mbps
  - Large recorders are currently at 240 / 107 Mbps
  - Smaller formats are trying to achieve 32 Mbps

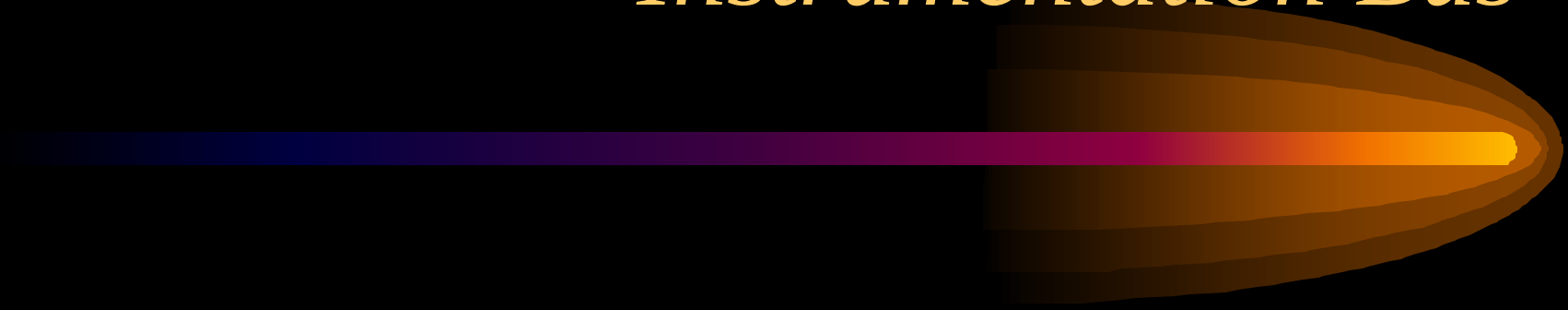
Conclusion

- Data acquisition networks are coming
- Challenges are being addressed
- A new era in instrumentation affordability, capability, and complexity will be born.

--- Coming up ---

NexGenBus Overview

Next Generation Instrumentation Bus



Sid Jones
NexGenBus Project Manager

Goal

- The goal of the NexGenBus Project is to establish a commercial communications bus as an interface standard for the test instrumentation system of the future.

Background

- Current data requirements exceed the capacity of any single instr. bus
- Increased fusion of data from numerous sources
  - Analog measurements/Avionics busses/Radar data/Video/Voice
- Instrumentation community needs a bus standard on which to base future systems

Background (cont.)

- Commercial standards show promise
- Leverage off industry's investment
  - Standards development
  - Interface hardware design (chipsets to test sets)
  - Large production quantities
- Range Commander's Council (RCC) task TG-50 concluded existing busses looked feasible and recommended a task to establish an IRIG Bus Standard

Project Description

- Office of Secretary of Defense (OSD) funded effort
  - Test Technology Development and Demonstration (TTD&D)
- Tri-service program participation
- The program is a three year effort
  - Year 1 - Define Requirements and research busses
  - Year 2 - Test and demonstrate bus(ses)
  - Year 3 - Write Profile

Completed Tasks

- Established bus requirements
- Located 33 possible commercial busses
- Identified 8 busses > 100Mbps
- Researched the 8 busses to determine 3 viable busses.
  - Fibre Channel — ANSI X3.230
  - Gigabit Ethernet — IEEE 802.3z
  - Firewire — IEEE 1394

Completed Tasks (cont)

- Down Select
  - The 3 busses were studied
  - Rated H/M/L for 13 criteria
    - Data Rate / Synchronicity / Class of Service / Protocols / Working Groups / Topologies / etc.
  - Converted ratings to numbers (average)
    - Fibre Channel 8.85
    - Gigabit Ethernet 5.00
    - Firewire 4.46

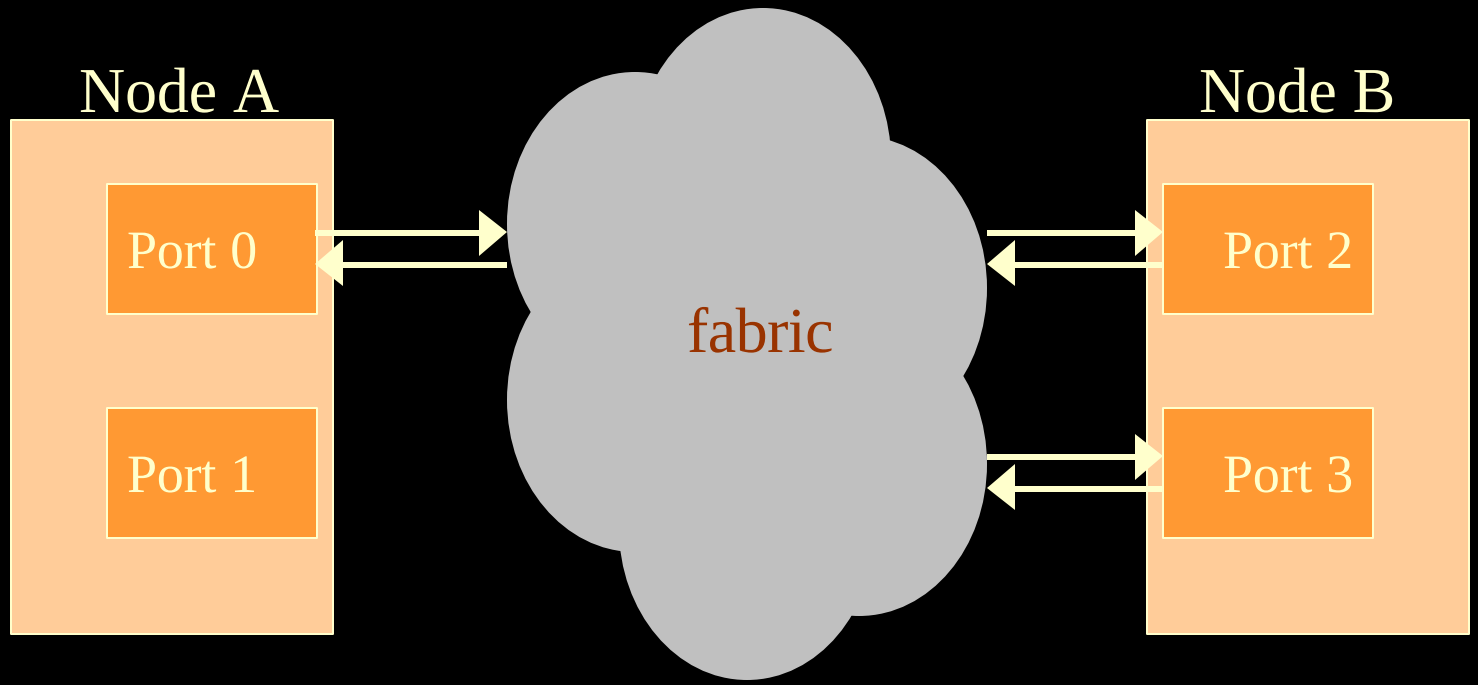
High:	10
Med:	5
Low:	1

Selected Bus for Testing

- *Fibre Channel was selected for follow-on testing*

- Of the three busses,
  Fibre Channel is the only one being used in a military flight environment

Fibre Channel: Nodes & Ports

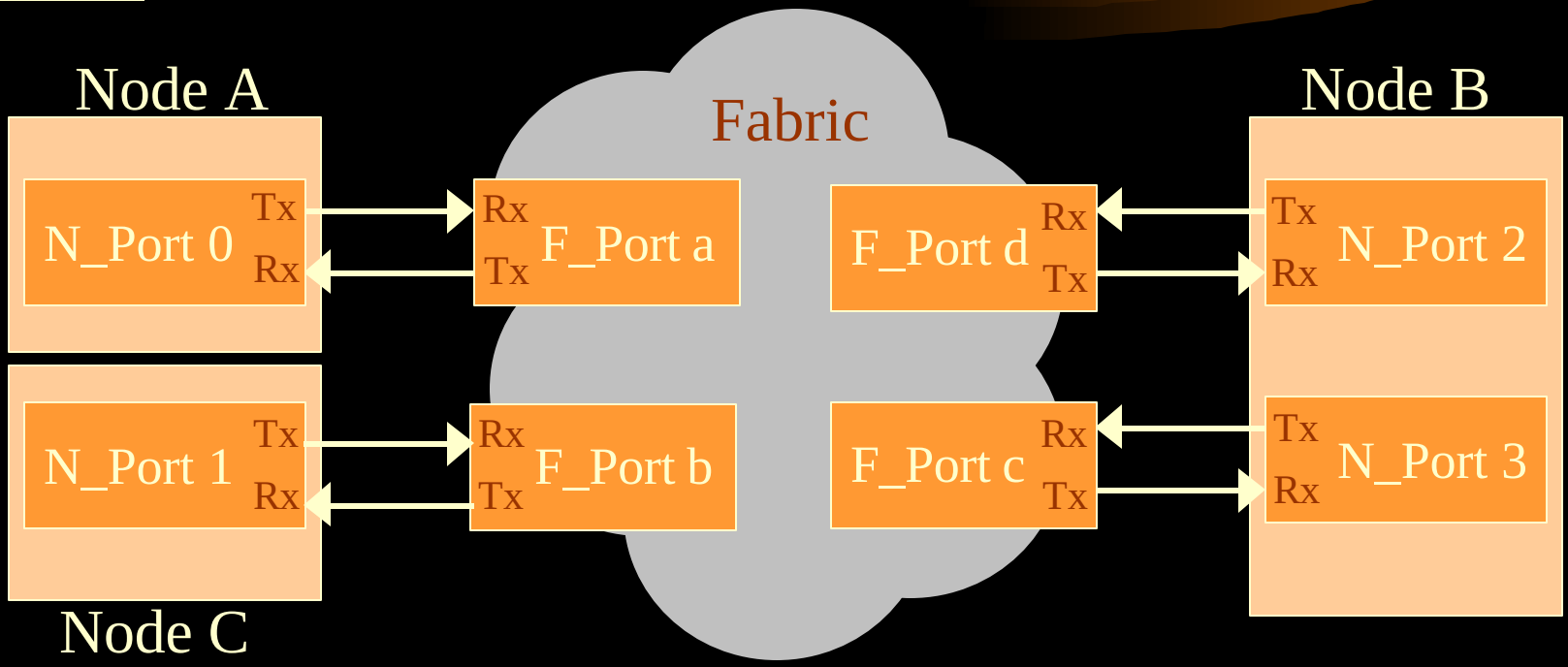


Fibre Channel: Topologies

Point-to-Point

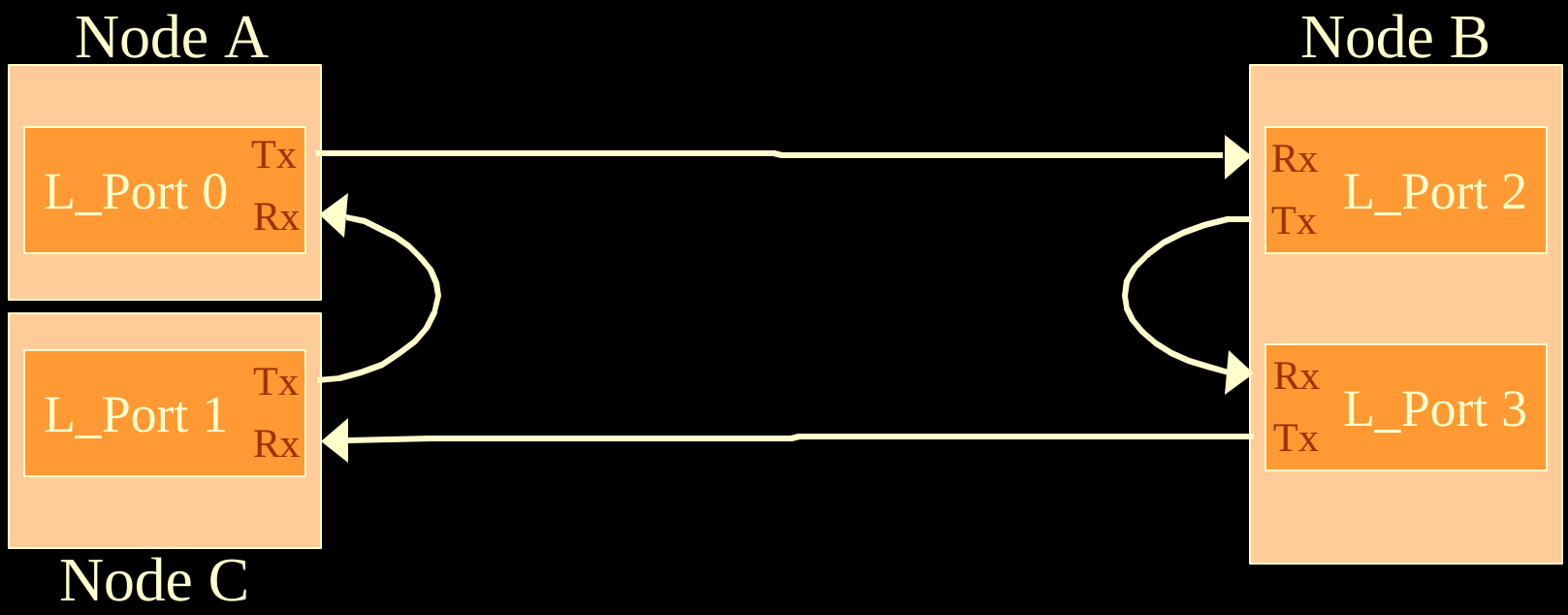
Fibre Channel: Topologies

Fabric



Fibre Channel: Topologies

Arbitrated Loop



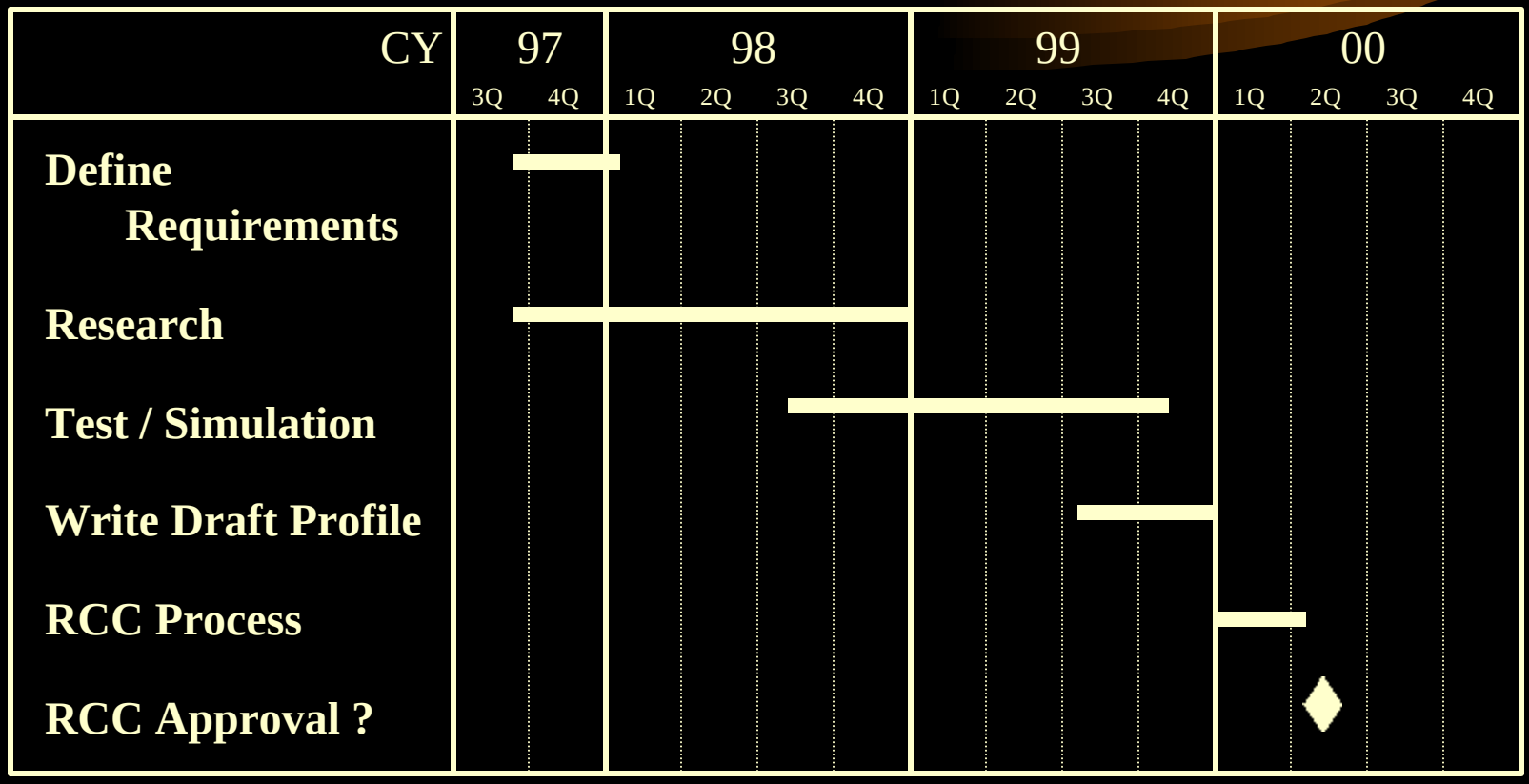
Fibre Channel Structure

Avionics Working Group

- Technical Committee T11.4 sponsors a Fibre Channel Avionics Environment (FC-AE) group
- FC-AE producing a “Profile” using Fibre Channel in an avionics environment

www.t11.org

Schedule


CY
97
3Q
4Q
98
1Q
2Q
3Q
4Q
99
1Q
2Q
3Q
4Q
00
1Q
2Q
3Q
4Q
Define Requirements
Research
Test / Simulation
Write Draft Profile
RCC Process
RCC Approval ?

Break

--- Coming up ---

Assessment of Fibre Channel

Assessment of Fibre Channel

Thomas Grace
Naval Air Warfare Center
Test Article Preparation

Approach

- Objective:
  - Determine as reasonably possible, can Fibre Channel meet our future Operational Requirements.
- Methods:
  - Analysis
  - Demonstration
  - Simulation

Methods

- Analysis
  - Port Functions
    - Physical Plant
    - Transmission Protocol
    - Signaling Protocol
  - Node Functions
    - Common Services
    - Mapping Layer for Upper-Level Protocol

Analysis Method

- Port Functions
  - Physical Plant
    - Cable assemblies
      - Fiber optic media
      - Copper media
      - Connectors
      - Operational environment
    - Transmitters and Receivers
      - Clock recovery
      - Bit error detection

Analysis Method

- Port Functions (continued)
  - Transmission Protocol
    - 8b/10b encoding/decoding
      - Ensures a minimum number of clock transitions while maintaining a dc balance and providing word alignment
    - Ordered sets
      - Identify frame boundaries and maintain the link
  - Signaling Protocol
    - Defines the rules for transferring blocks of data
      - Frame structure and byte sequences

Analysis Method

- Node Functions
  - Common Services
    - Set of services that are common across multiple ports of a node
  - Mapping Layer
    - Defines the steps required to perform the functions identified by a Upper-Level Protocol
      - Each ULP requires a corresponding mapping

Analysis Results

- Determined that most of the test elements could not be isolated for testing.
- Identify specific test objectives for Demonstration and Simulation.
  - Demonstration
    - Physical plant
  - Simulation
    - Node to Node functions

Analysis Results

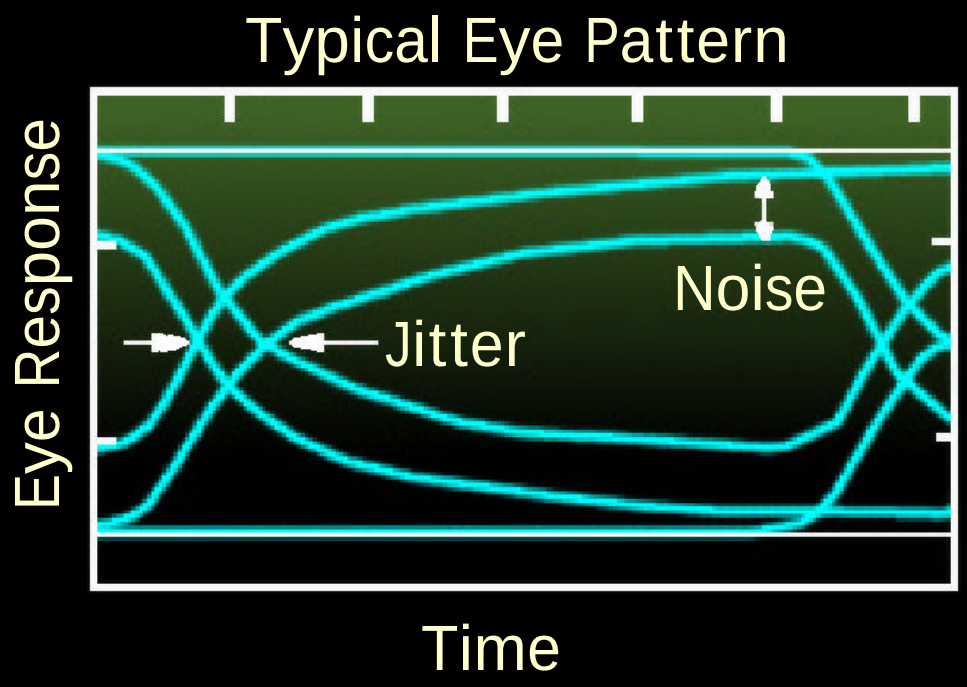
- Test objectives for Demonstration
  - Physical Plant
    - Eye-diagram waveform test
    - Cable interoperability test
    - Transmission rate test
    - Noise rejection test

Analysis Results

- Fiber Optic assemblies not tested
- Cable assemblies for the tests
  - Gore Quad (balanced pair)
    - FCN-1056 w/Mil-C-38999 style connector
  - Mil-C-17/94 (unbalanced)
    - RG-179 w/BNC connector
  - Mil-C-17/110 (unbalanced)
    - RG-302 w/BNC connector

Demonstration Method

- Eye-diagram waveform
  - Overall signal quality



  - Jitter
    - bit times
    - differential skew
    - rise and fall times
  - Noise
    - attenuation
    - rise and fall times

Demonstration Method

- Cable interoperability
  - cable length
  - connector loss
- Transmission rate
  - maximum frame data rate
- Noise rejection
  - simulate EMI interference

Demonstration Method

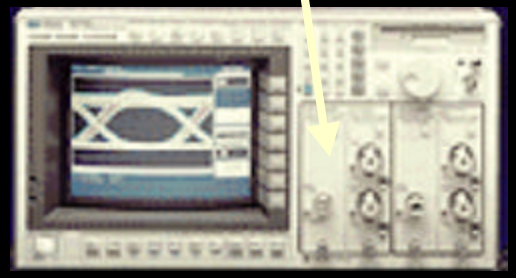
- Test data transmission
  - Valid Fibre Channel data sequences
    - Low frequency pattern
    - Low transition density pattern
    - Jitter tolerance pattern
    - Random data pattern
    - Supply noise data pattern

Demonstration Method

- General Test Setup

Hub

FC Generator

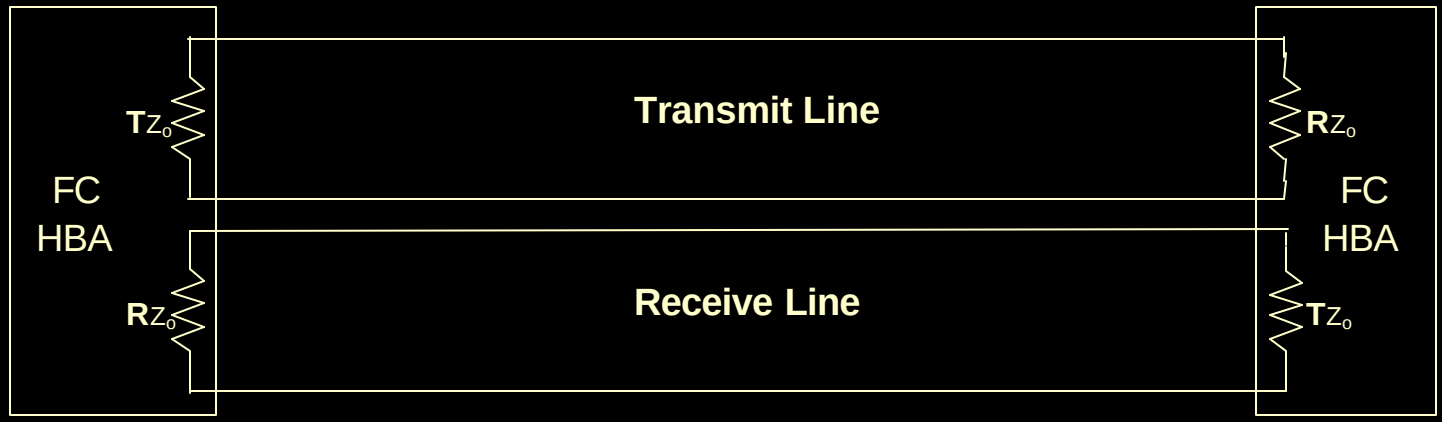


Communications Analyzer

FC Analyzer

Demonstration Method

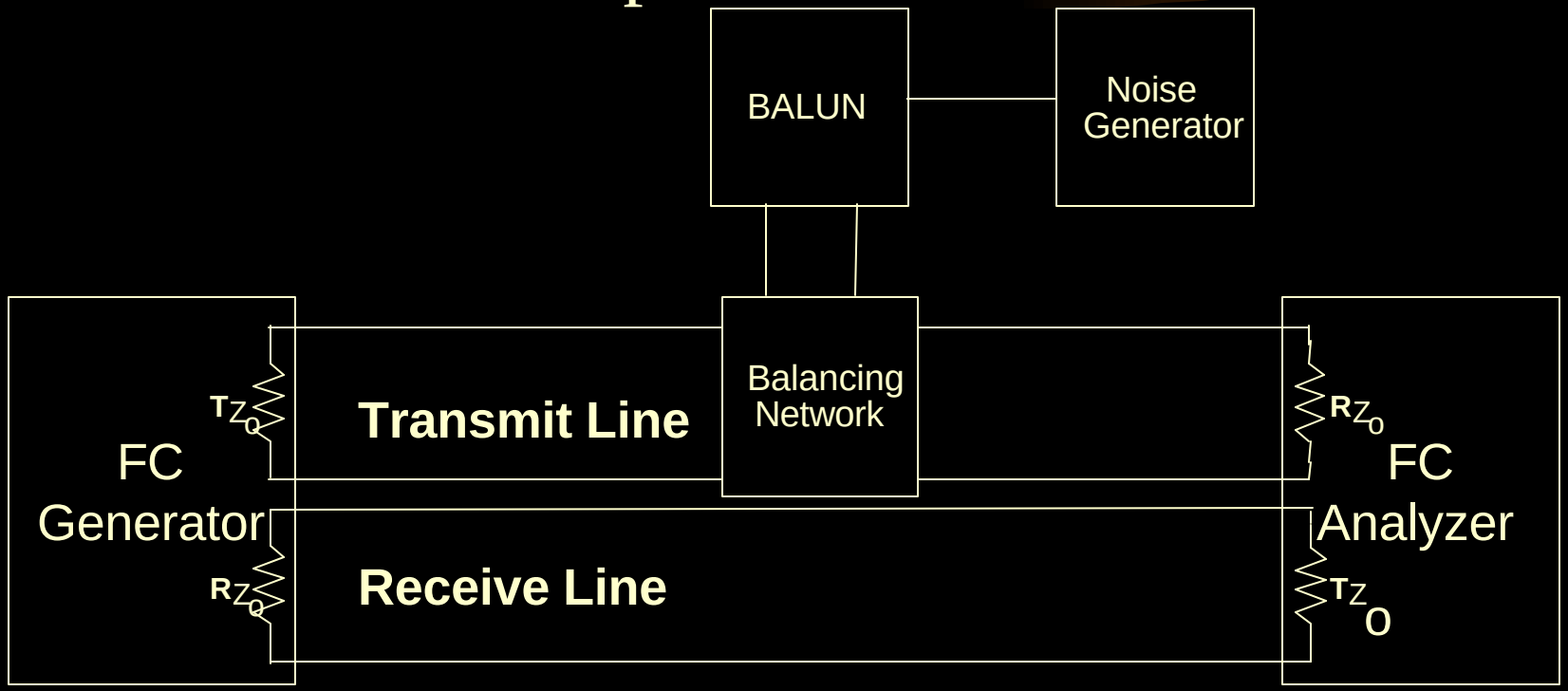
- Transmission Rate Test Setup



HBA = Host Bus Adapter

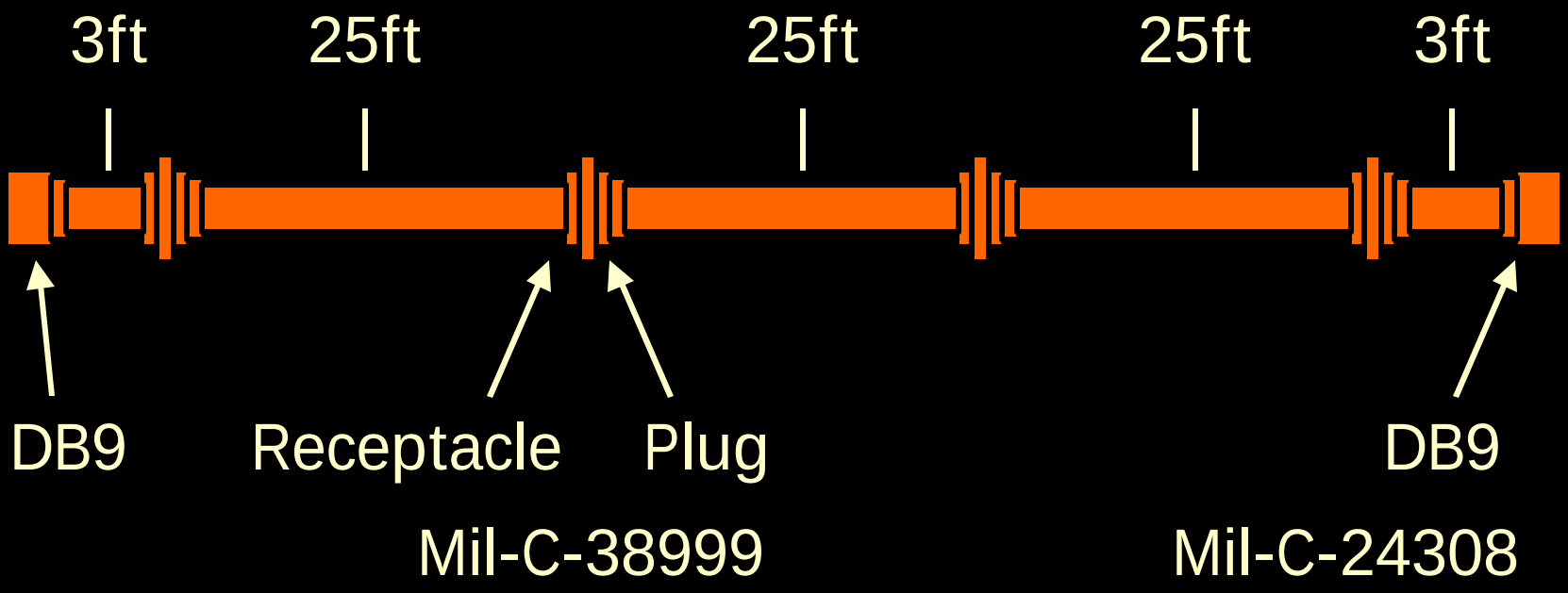
Demonstration Method

- Noise Test Setup



Demonstration Method

- Quad Cable Layout



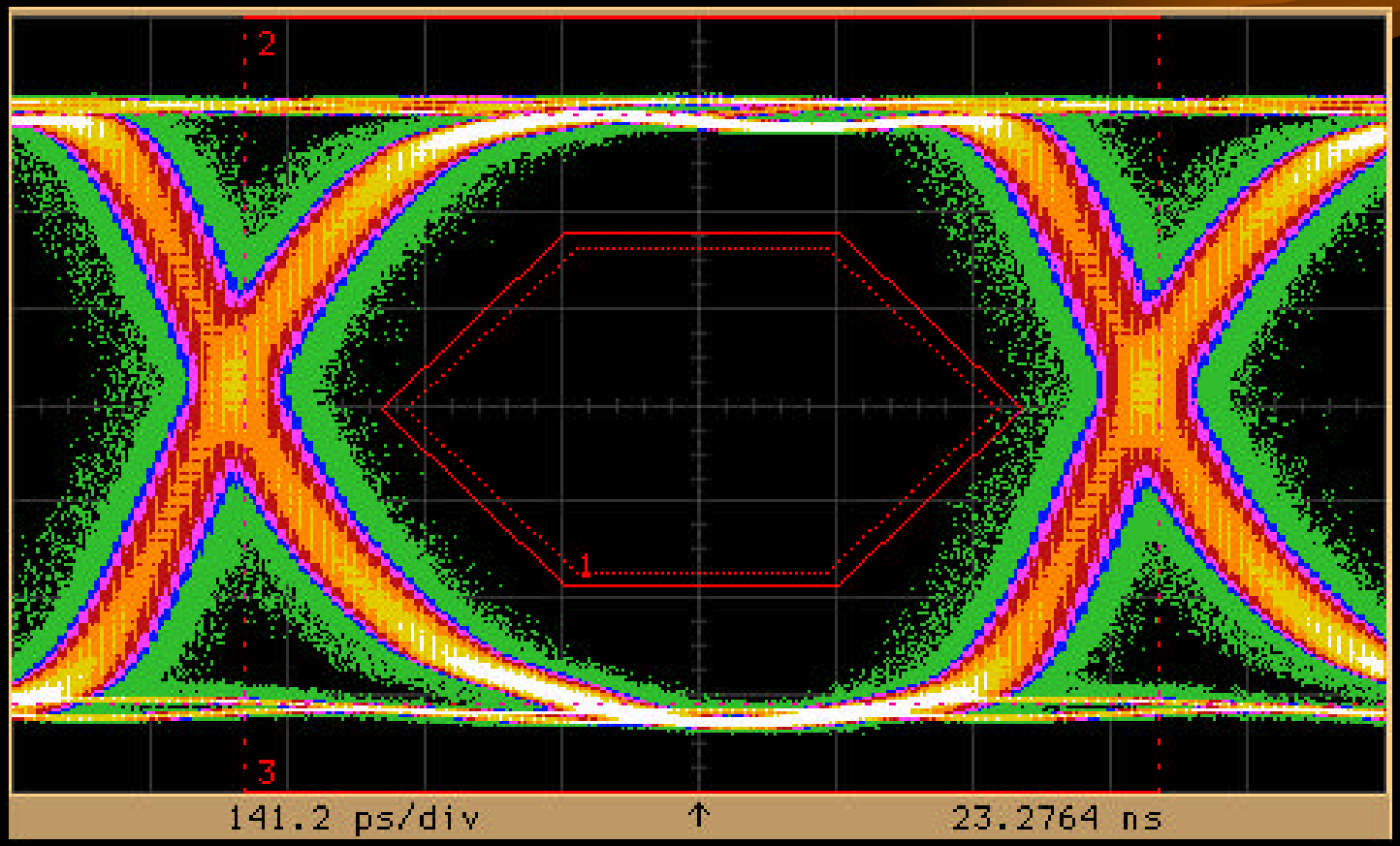
Demonstration Results

- Eye Waveform Test
  - Quad Cable assembly meet spec
  - RG-179 assembly is limited
  - RG-302 assembly is limited
- Cable Interoperability Test
  - Quad Cable assembly meet spec
  - RG-179 assembly is limited
  - RG-302 assembly is limited

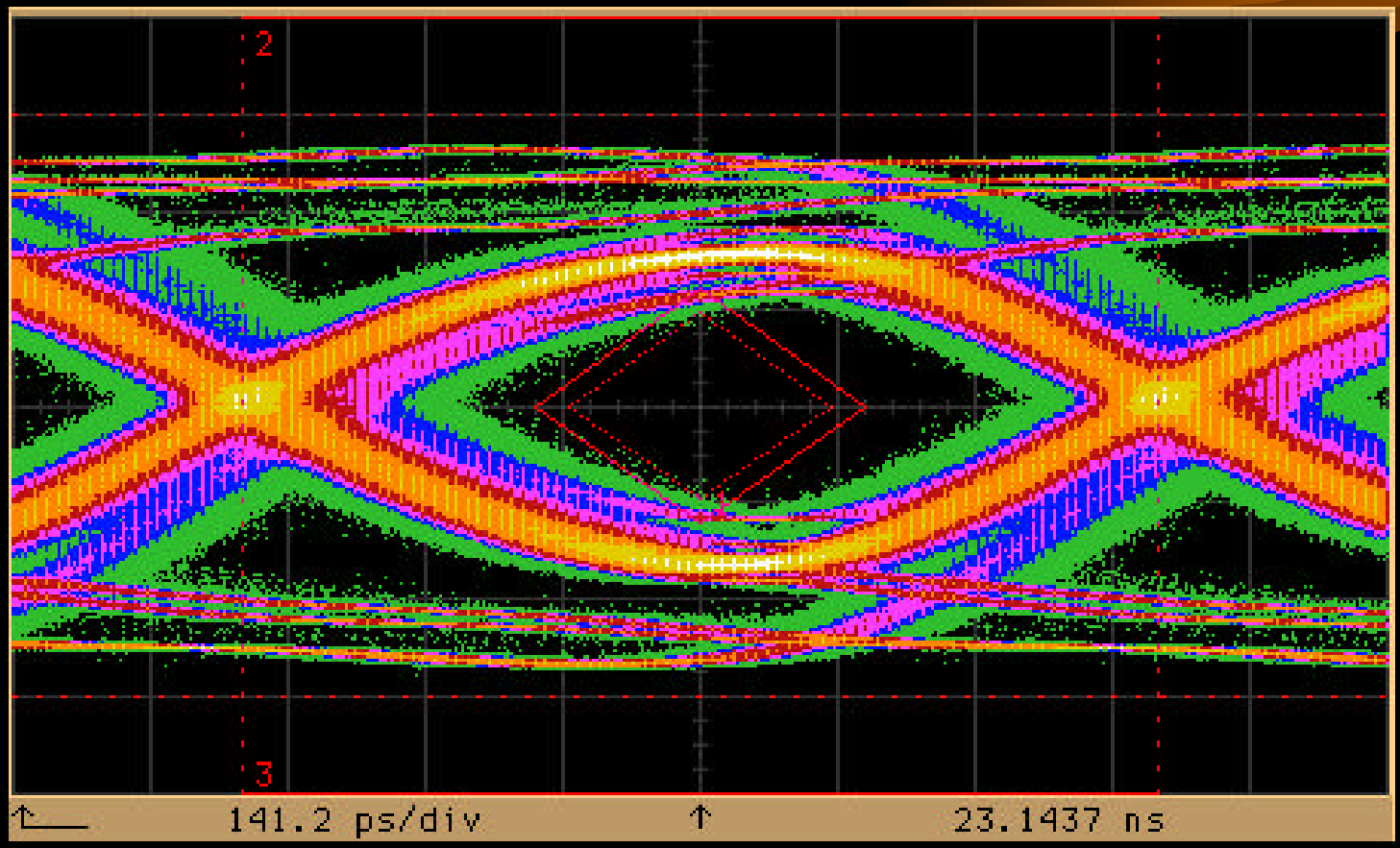
Demonstration Results

- Transmission rate
  - Systran (HP Tachyon chip)
    - 55Mbytes/sec
  - Emulex (QLogic ISP chip)
    - 85Mbytes/sec
- Noise rejection test
  - errors detected with a S/N ratio of 5.4

Transmit Eye Pattern

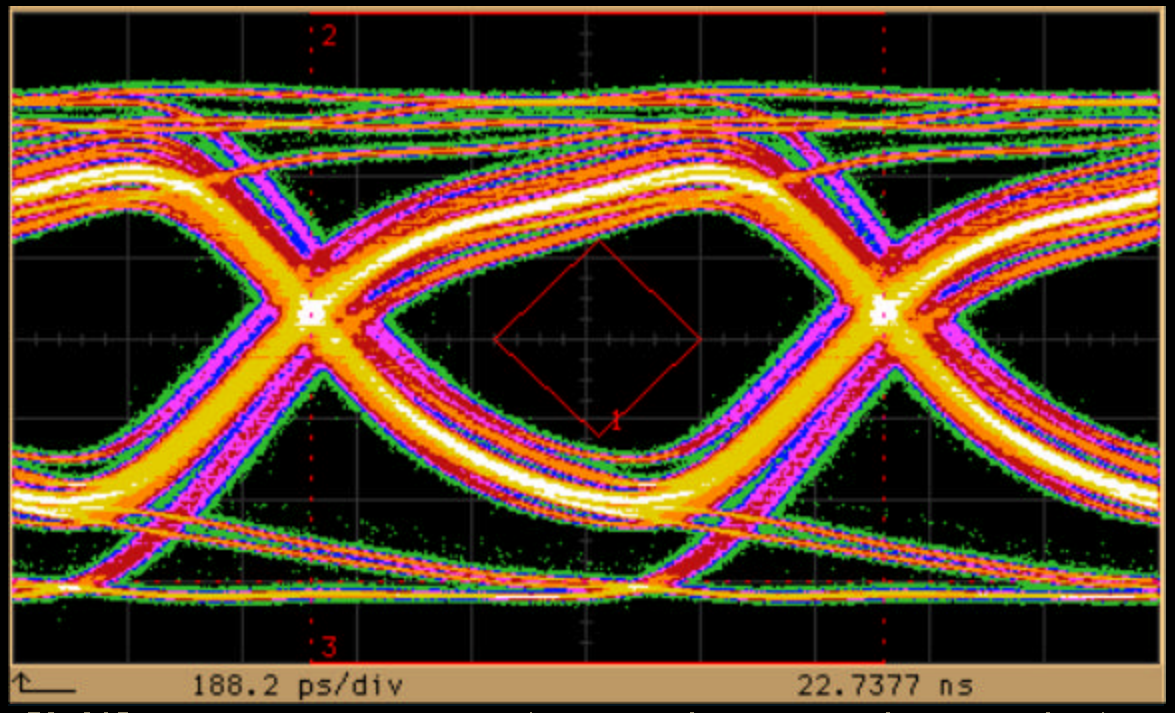


Receiver Eye Pattern
Gore Quad Cable Results



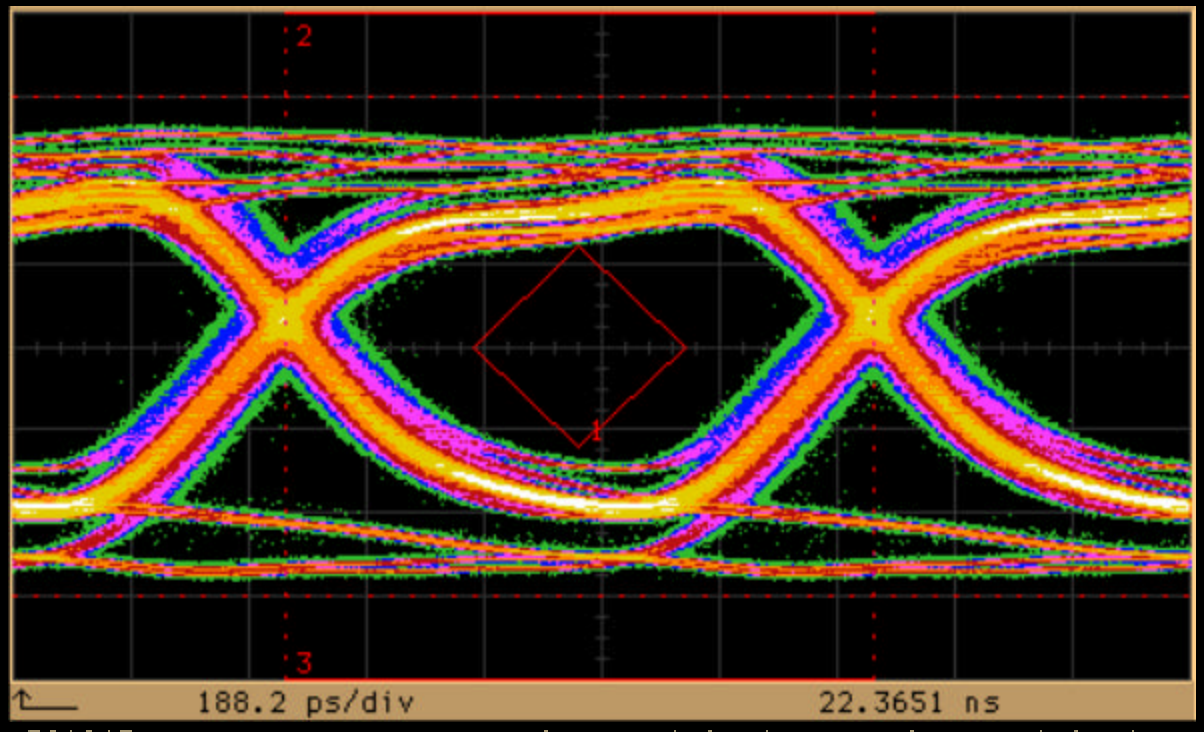
Receiver Eye Pattern RG-179 Cable Results

- Receive signal
  - normalized to 28 feet

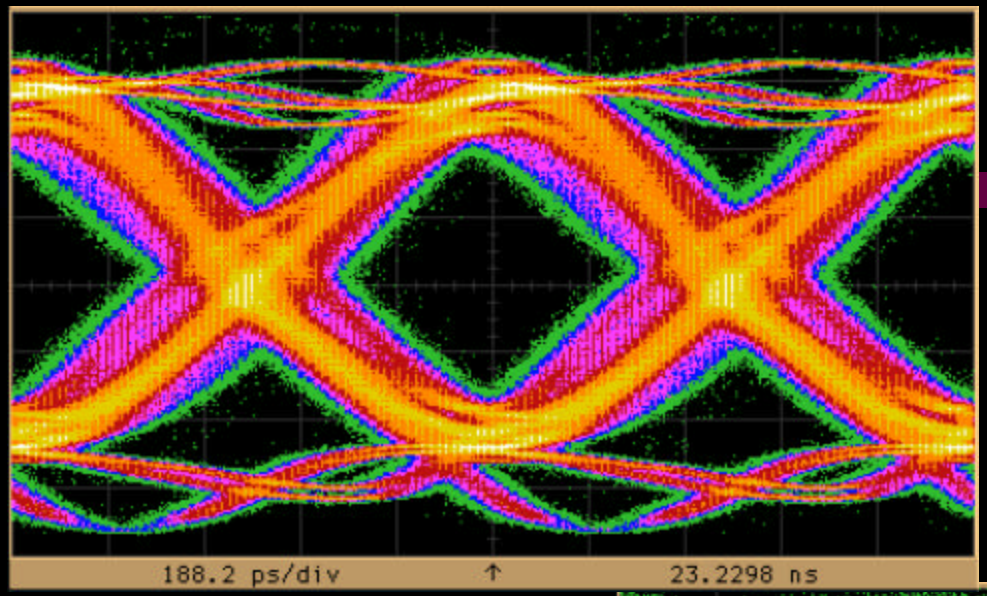


Receiver Eye Pattern RG-302 Cable Results

- Receive signal
  - normalized to 38 feet

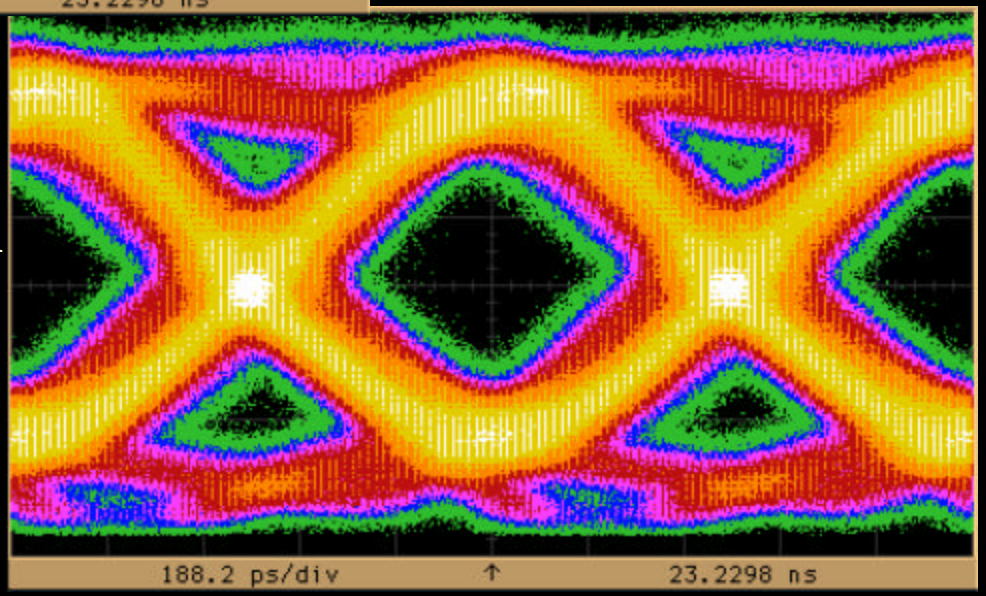


Noise Results



- Receive signal

- Receive signal with noise



Cable Plant Summary

Cable	**Cable Loss (dB/ft)**		**Conn. Loss (dB/Conn)**		**Max Cable Length (ft)**		
(1 Gbaud)	Spec	Meas	Spec	Meas	Spec	Meas	Norm
Quad	.143	.150	.50	.52	65.6	66	81
RG-179	.240	.325	.25	.30	18.4	15	28
RG-302	.260	.167	.25	.16	78.7	25	38

Summary of Boeing Test Results

- Twisted Shielded Pair
  - could support only data rates at 1/4x and below
  - did not pass emissions testing (RE102)
  - Testing suspended after emissions failure
- Triaxial Cable
  - could not support 1 Gbaud (72ft)
  - able to pass radiated susceptibility (RS103)
    - at 42ft - marginal performance at 531 Mbaud

Summary of Boeing Test Results

- Coaxial Cable (Mil-C-17/175- 50Ù)
  - supported data transmission at 1 Gbaud
  - passed RE102 and CS114 tests at 1 Gbaud
  - RS103 showed marginal bit error performance at 200 V/m (1 Gbaud)
  - cable may be a good choice for future applications

Summary of Boeing Test Results

- Quad Cable
  - easily passed all emissions and susceptibility tests
  - easily supported 1 Gbaud transmission
  - passed vibration testing - random and sinusoidal, using aircraft composite profiles
  - Crosstalk: -29 dB at 500 MHz

Summary

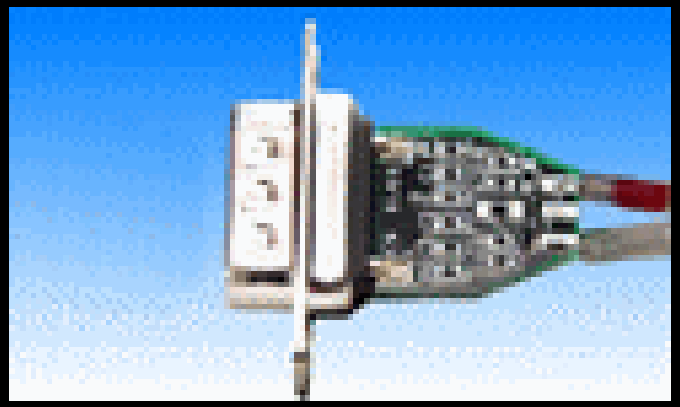
- One Gbaud data rate with copper media
- Quad cables perform well
  - excellent signal integrity - high cost
- Coax cables limited performance
  - good for short runs - low cost
- Test are independent of topology
  - point to point oriented

Close

- FC is expanding to 2 Gbaud and 4 Gbaud
- Can copper media support higher rates?
  - Currently works at 1 Gbaud
- Copper media is being massaged to work
  - Can it keep up?
- FC supports fiber optic media
  - Recommend investigating for backbone use

Why not STP?

- standard specifies for 266Mbaud (1/4x)
- Equalization
  - for long lengths
  - fixed cable assemblies
  - solid conductor?



Break

--- Coming up ---

Simulating an Instrumentation Network

Simulating an Instrumentation Network

Tom DeSelms

Eagan, McAllister Associates, Inc

Simulation Overall Objectives

- Determine Message Latency & Throughput
- Evaluate effect of Upper Layer Protocols
- Evaluate different Classes of Service
- Measure Synchronization
- Evaluate Fibre Channel Topologies

Simulation Method

- Generate Network Modeling and Simulation Plan
- Develop Baseline Model
- Build Lab Network
- Perform Verification on Baseline Model
- Document Initial Simulation Results

Simulation Method (cont'd)

- Generate Expanded Model Capabilities and Assumptions Document
- Build Small, Medium (today's max) and Large (tomorrow's max) Simulations
- Document results of Small, Medium and Large Simulations

Baseline Model

- Matches the performance characteristics of the lab network
- Systran FXLP protocol simulation in each transaction
- Fibre Channel data link uses vendor specifications

Lab Network

- Lab consists of two Pentium PC's
- Windows NT 4.0
- Systran PCI card with FXLP drivers
- Twinax cabling between PC's
- Visual C++ program

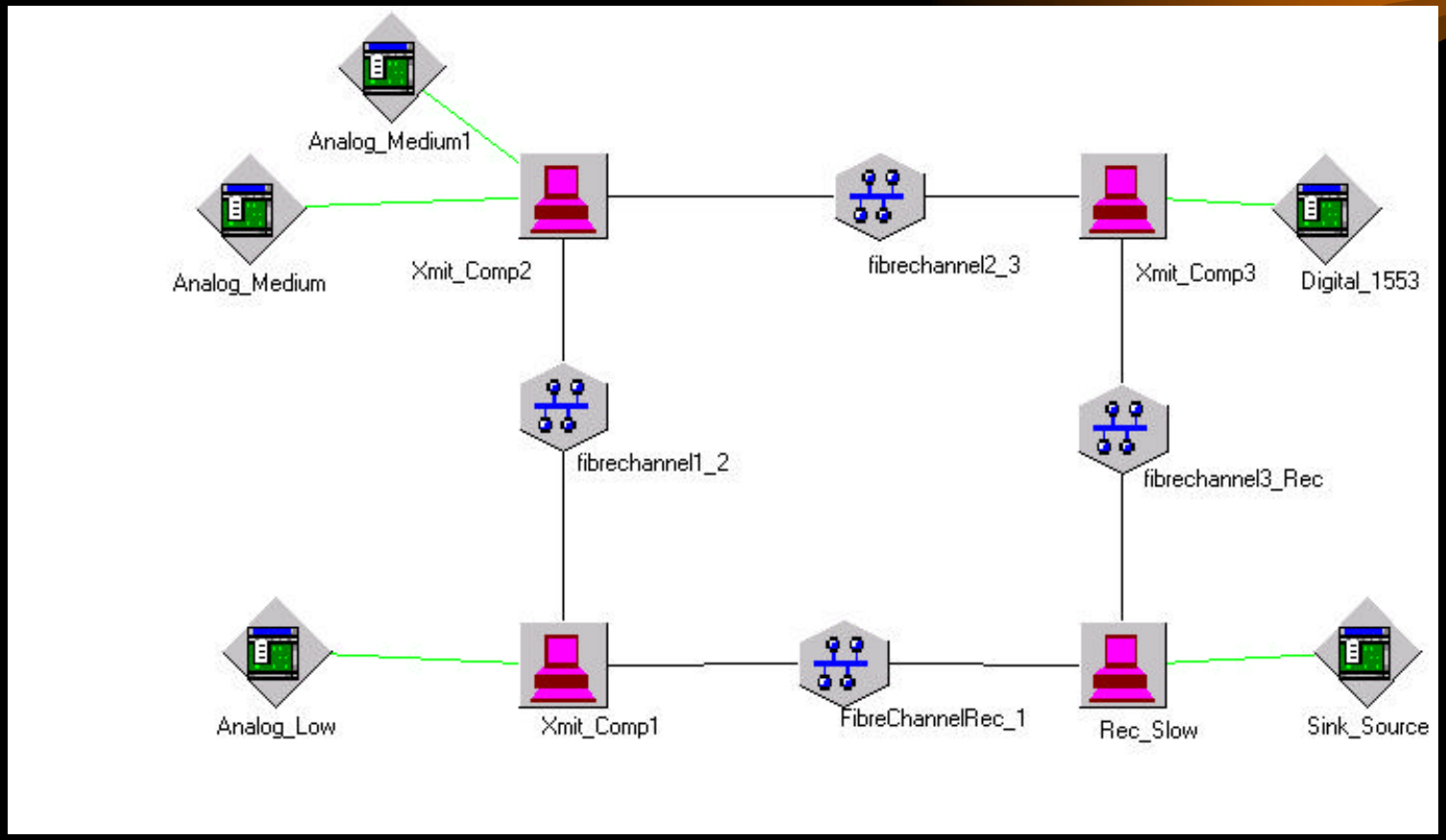
Initial Model Results

- All file transfers performed 1000 times for statistical averages
- Simulation and Lab test throughput match within 5%
- Fibre Channel link not utilized over 50% during any of the file transfers

Expanded Models

- Objective: Build on initial Model to simulate small, medium and large systems
  - Simulate Message Latency and Throughput
  - Simulate effect of Upper Layer Protocols
  - Simulate different Classes of Service
  - Simulate Synchronization
- Goal: Evaluate above effects on instrumentation systems

Small Model


Analog_Medium1
Analog_Medium
Xmit_Comp2
fibrechannel2_3
Xmit_Comp3
Digital_1553
fibrechannel1_2
fibrechannel3_Rec
Analog_Low
Xmit_Comp1
FibreChannelRec_1
Rec_Slow
Sink_Source

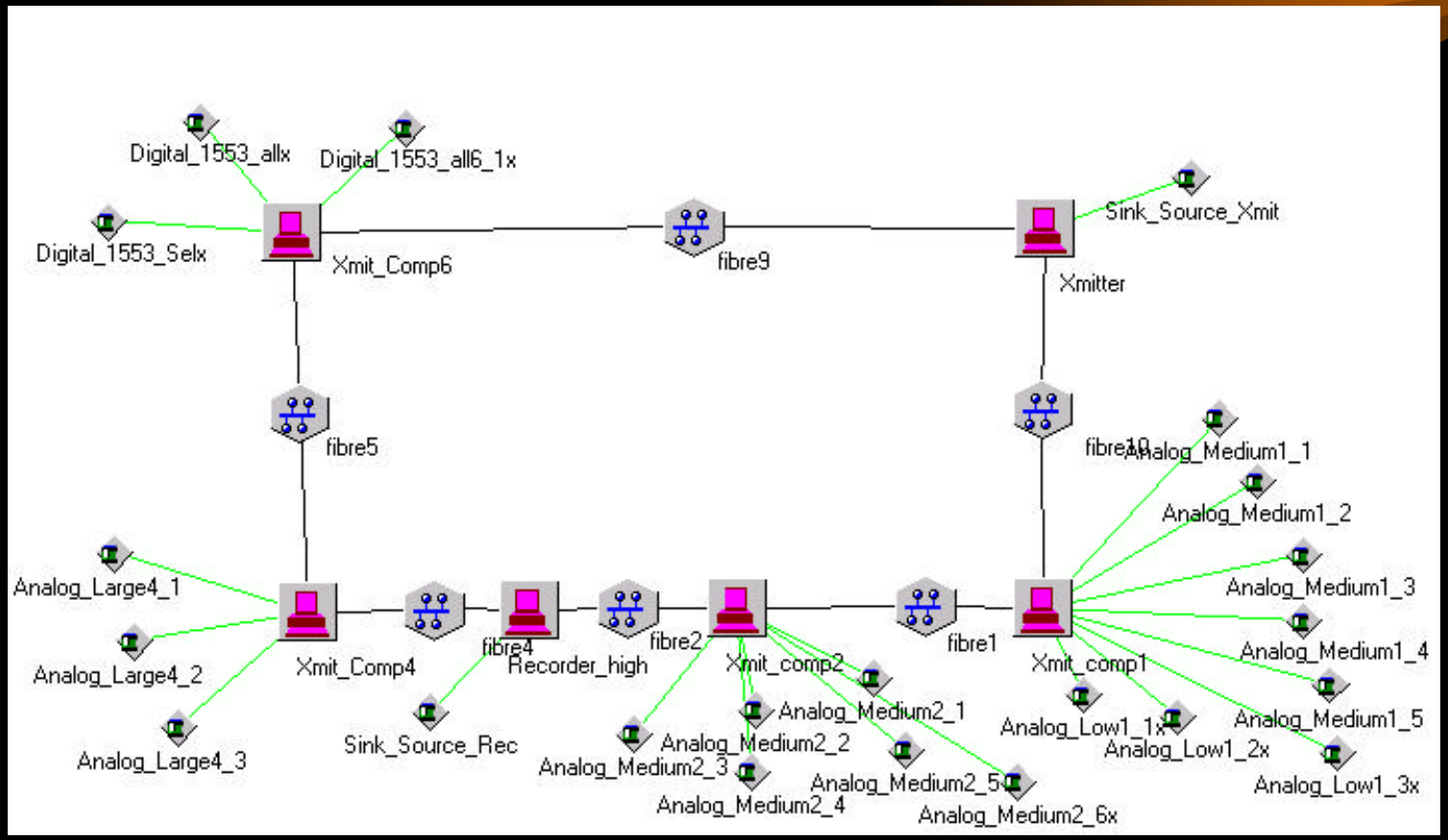
Small Model (cont'd)

- Four nodes
  - One low speed analog node 50 ms, 1.06 kB
  - One medium speed analog node 1 ms, 1.05 kB
  - One digital 1553 bus node 50 ms, 3.5 kB
  - Recorder (receives all data)

Small Model Simulation Results

- Fibre Channel link - Arbitrated Loop
  - Avg. message latency 40 μs
  - Avg. throughput 2.67 MBps
  - Avg Utilization 0.99%
  - TCP/UDP/IP protocols simulated with little difference
  - Synchronization and topology not addressed

Medium Model



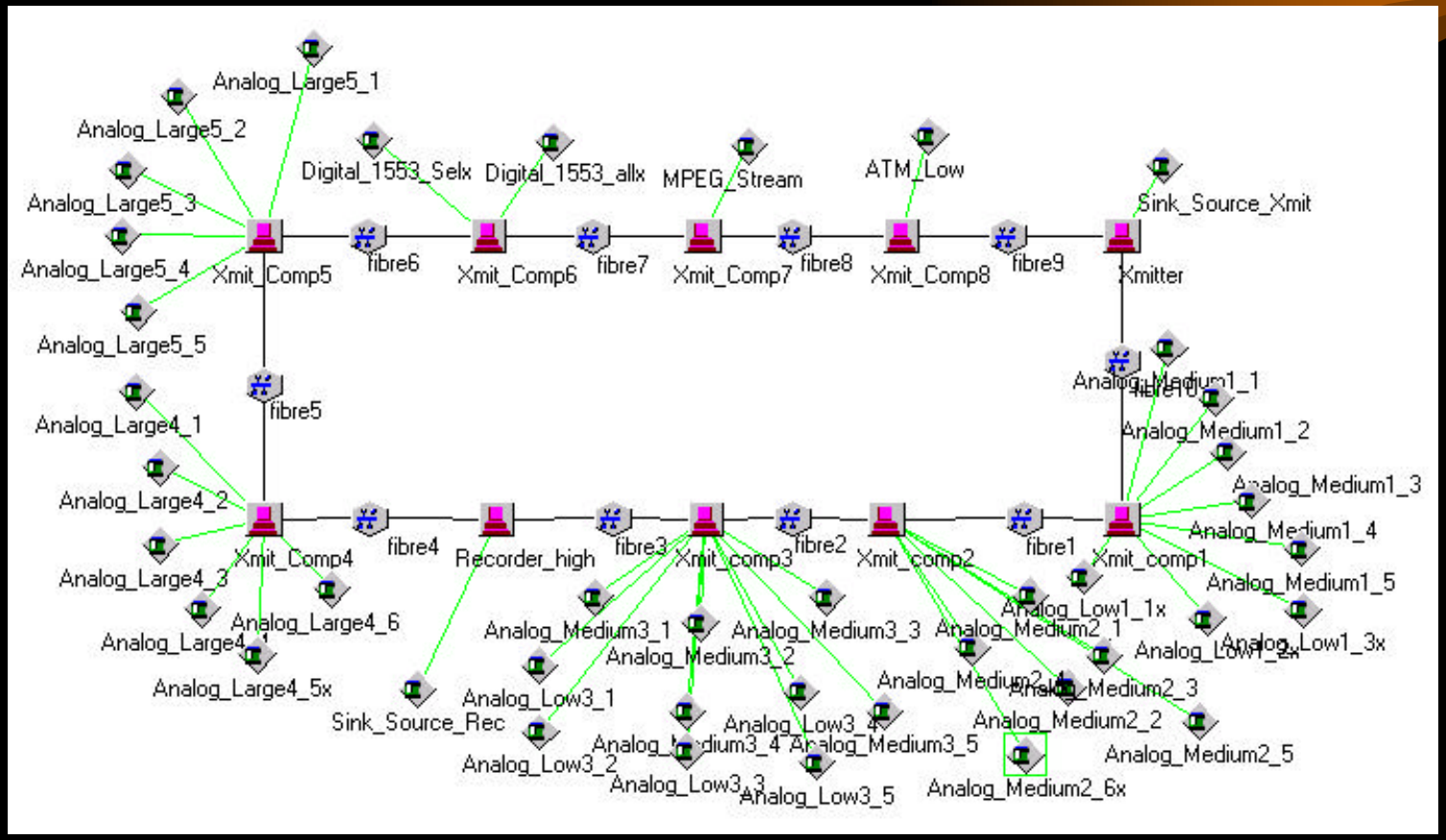
Medium Model (cont'd)

- Six nodes
  - Three nodes: a combination of low, medium and high speed analog sources
  - Fourth Node: three digital 1553 bus sources
  - Fifth Node: recorder
  - Sixth Node: transmitter

Medium Model Simulation Results

- Fibre Channel link
  - Avg. message delay 60 μs
  - Avg. throughput 8.16 Mbps
  - Avg Utilization 5.66%
  - TCP/UDP/IP protocols simulated with little difference
  - Synchronization and Topology not addressed

Large Model


Analog_Large5_1
Analog_Large5_2
Analog_Large5_3
Analog_Large5_4
Analog_Large5_5
Digital_1553_Selx
Digital_1553_allx
MPEG_Stream
ATM_Low
Sink_Source_Xmit
Xmit_Comp5
fibre6
Xmit_Comp6
fibre7
Xmit_Comp7
fibre8
Xmit_Comp8
fibre9
Xmitter
fibre5
Analog_Large4_1
Analog_Large4_2
Analog_Large4_3
Analog_Large4_4
Analog_Large4_5x
Analog_Large4_6
Xmit_Comp4
fibre4
Recorder_high
fibre3
Xmit_comp3
fibre2
Xmit_comp2
fibre1
Xmit_comp1
Analog_Medium1_1
Analog_Medium1_2
Analog_Medium1_3
Analog_Medium1_4
Analog_Medium1_5
Analog_Low1_1x
Analog_Low1_3x
Analog_Medium2_1
Analog_Medium2_2
Analog_Medium2_3
Analog_Medium2_5
Analog_Medium2_6x
Analog_Medium3_1
Analog_Medium3_2
Analog_Medium3_3
Analog_Medium3_5
Analog_Low3_1
Analog_Low3_2
Analog_Low3_3
Analog_Low3_4
Analog_Low3_5
Sink_Source_Rec

Large Model

- 10 nodes
  - five nodes a combination of low, medium and high speed analog sources
  - one node with two digital 1553 busses
  - one node a video MPEG stream
  - one node a ATM source
  - one recorder and one transmitter node
  - one processing node

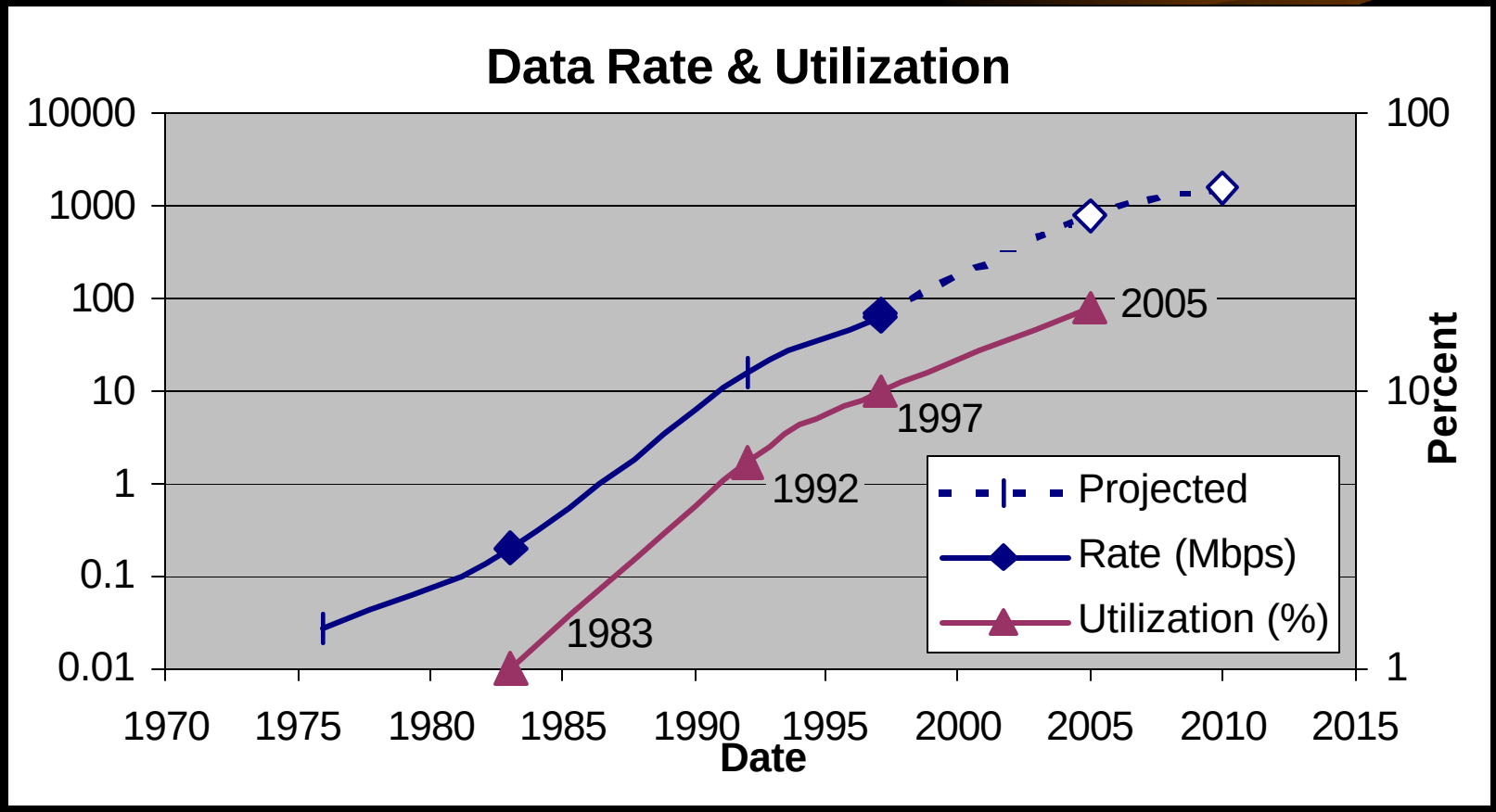
Large Model Simulation Results

- Fibre Channel Link using IP
  - Avg. message latency 86 ms
  - Avg. Throughput 13.3 Mbps
  - Avg. Utilization 20.02%
- Upper Layer Protocols
  - UDP produced similar results, not recommended for SCSI
- Topology not addressed

Large Simulation Model Results

- TCP/IP increases utilization 10%, adds message delay of 100 ms
- TCP/IP decreases throughput to 8.4 Mbps
- Predicted Transmission delay 2.4 μs simulation approx. 56 μs
  - IP stack causes additional delay

Overall Simulation Results



Overall Simulation Results

- Arbitrated Loop only topology simulated
  - Fabric not simulated
- Utilization tracking data rate growth
- 2005 timeframe moving to 2-4 Gbps
- Message delays depend on # of nodes

Break

--- Coming up ---

NexGenBus Profile and Discussion

NexGenBus Profile

Sid Jones
NexGenBus Project Manager

Scope

- Minimum required to achieve interoperability between multiple vendors' end-items on a Fibre Channel instrumentation bus.
- This document only addresses the ability to move the data.
  - Data format is beyond the scope

Avionics Working Group

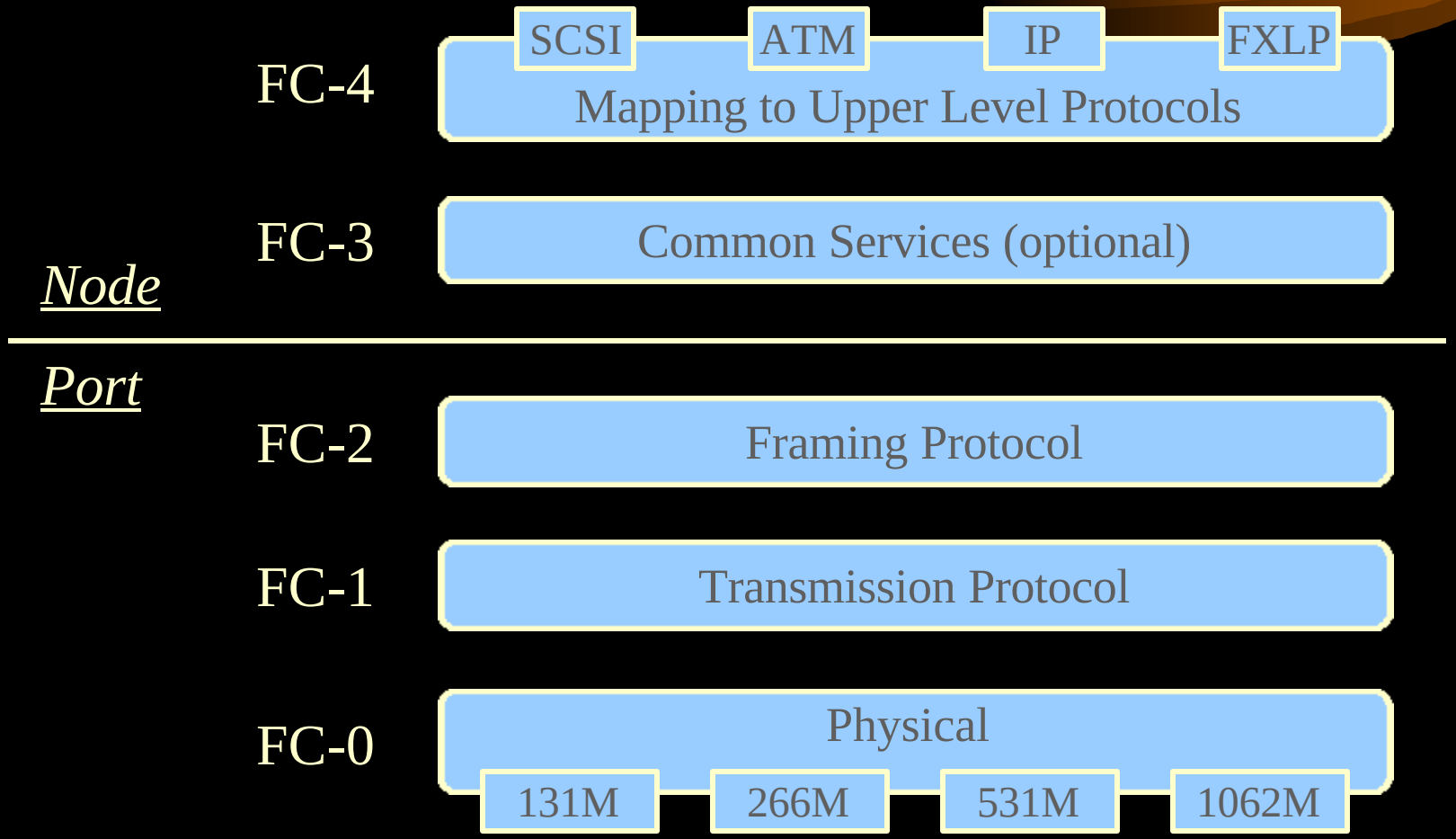
- Technical Committee T11.4 sponsors a Fibre Channel Avionics Environment (FC-AE) group
- Produce a “Profile” using Fibre Channel in an avionics environment
  - Profile: an adaptation of a given standard for a particular application

www.t11.org

Order of Precedence

- The order of precedence for instrumentation interoperability shall be:
  - This document
  - The FC-AE profile (when published)
  - The Fibre Channel suite of standards.

Fibre Channel Structure

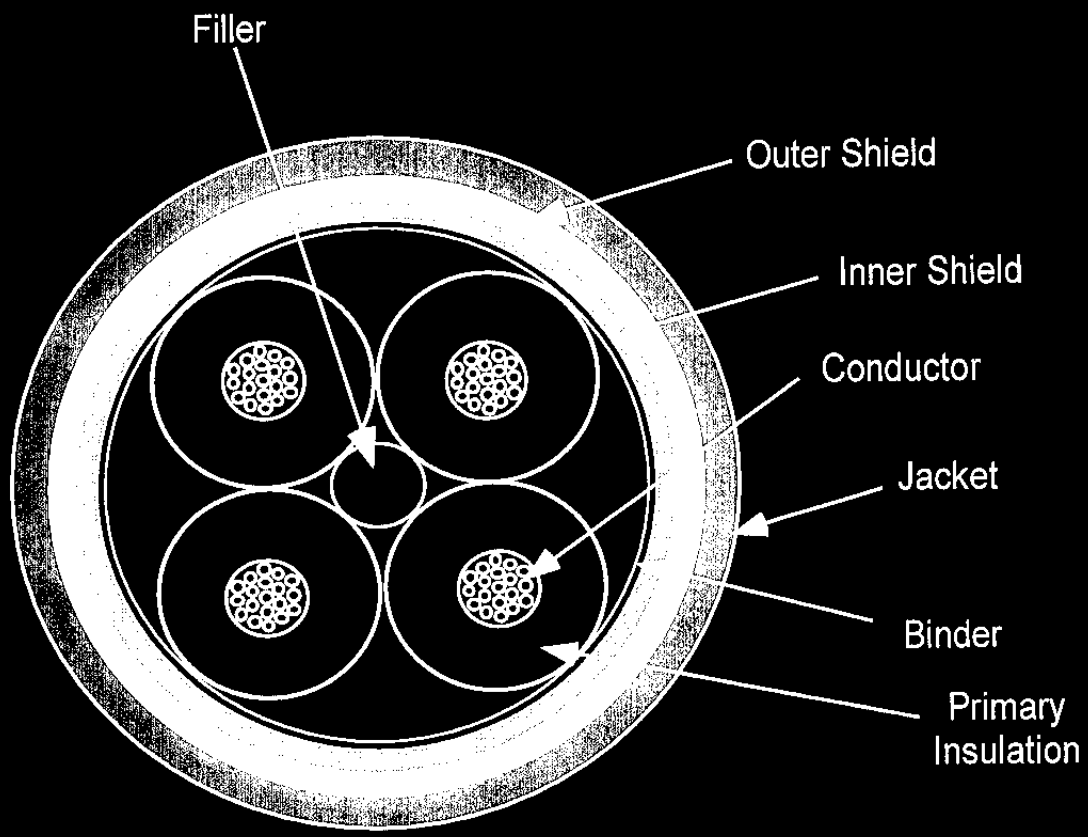


Fibre Channel Level 0 (FC-0)

Physical Characteristics

- Cables
  - Quad Cable / Coax
- Connectors
  - Mil-38999 style / BNC &TNC
- Signaling Rate
  - 1,063 Mbaud

Gore Cable


Filler
Outer Shield
Inner Shield
Conductor
Jacket
Binder
Primary
Insulation

Fibre Channel Level 1 (FC-1)

Transmission Protocol

- No Changes

Fibre Channel Level 2 (FC-2)

Signaling and Framing Protocol

- Port Type
  - NL_Port
- Login
  - Implicit
- Class of Service
  - Class 3

Fibre Channel Level 3 (FC-3)

Common Services

- No Changes

Fibre Channel Level 4 (FC-4)

Protocol Mapping

- Upper Level Protocol (ULP)
  - TBD
  - What's been looked at so far:
    - IP - Internet Protocol
    - SCSI - Small Computer System Interface
    - FXLP - Fibre Express Lightweight Protocol (Systran)

Informative Annex

- Topics that may make a system more useful, but not required for interoperability
  - Architecture
  - Open System
  - Topology

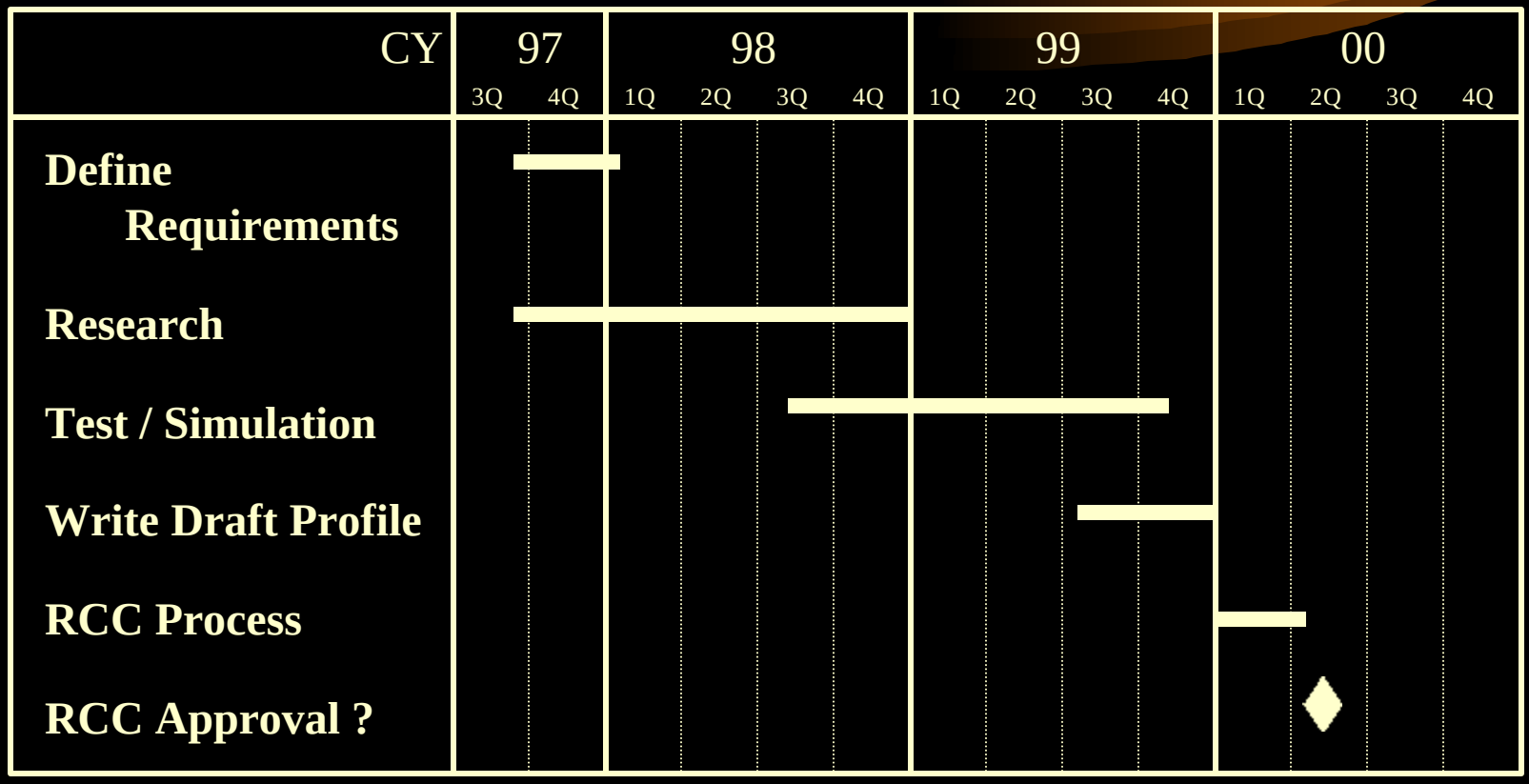
Informative Annex - cont.

- Fault Tolerance
  - Port Bypass
  - Hub
  - Redundancy
  - Addressing
- Timing
  - Data Correlation
  - Simultaneous Sampling
  - Data Source Reconstruction

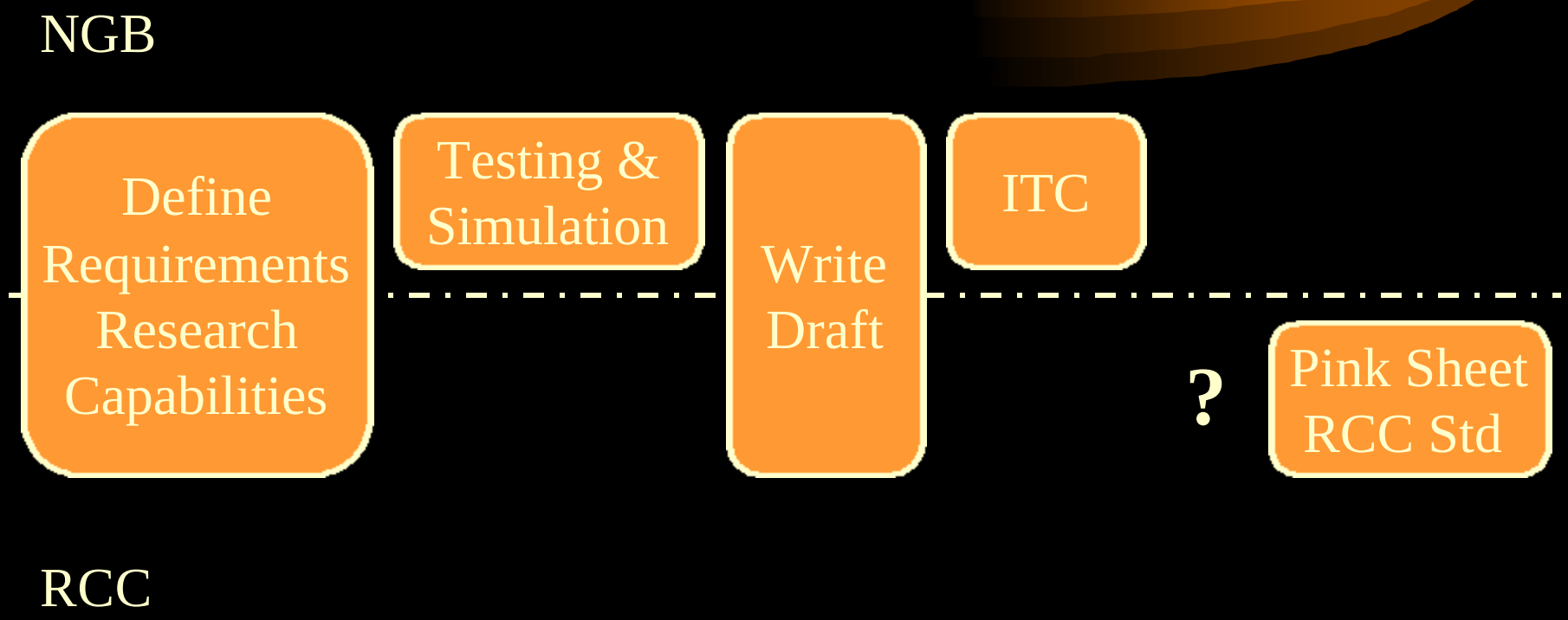
Informative Annex - cont.

- Interoperability
  - Physical
  - Port Type
  - Signaling Rate
  - Login
  - Class of Service
  - Protocol

Schedule


CY
97
3Q
4Q
98
1Q
2Q
3Q
4Q
99
1Q
2Q
3Q
4Q
00
1Q
2Q
3Q
4Q
Define Requirements
Research
Test / Simulation
Write Draft Profile
RCC Process
RCC Approval ?

The Process


NGB
Define Requirements Research Capabilities
Testing & Simulation
Write Draft
ITC
?
Pink Sheet RCC Std
RCC

Responsibility / Maintenance

- Interoperability Issues (Profile)
  - RCC Telemetery Group
- Capability Issues (Fibre Channel)
  - ANSI T11 / FC-AE

Comments

- Let us know your comments
  - On NexGenBus
  - The Profile draft as written
  - The Profile as it should be written
  - The direction instrumentation is going
- Email list signup sheet

More Information

- NexGenBus
  - http://NexGenBus.Nawcad.Navy.Mil
  - Sid Jones, Project Manager
    - 301-342-1601 x32
    - JonesSR@Navair.Navy.Mil
- Fibre Channel (ANSI T11)
  - http://WWW.T11.ORG
  - Open meetings every other month (Dec 6-9)